Influence of a proximal margin elevation technique on marginal adaptation of ceramic inlays

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Abstract: PURPOSE: Evaluating the effect of a proximal margin elevation technique on marginal adaptation of ceramic inlays. METHODS: Class II MOD-cavities were prepared in 40 human molars and randomly distributed to four groups (n = 10). In group EN (positive control) proximal margins were located in enamel, 1 mm above the cementoenamel junction, while 2 mm below in groups DE-1In, DE-2In and DE. The groups DE-1In, DE-2In and DE simulated subgingival location of the cervical margin. In group DE-1In one 3 mm and in group DE-2In two 1.5 mm composite layers (Tetric) were placed for margin elevation of the proximal cavities using Syntac classic as an adhesive. The proximal cavities of group DE remained untreated and served as a negative control. In all groups, ceramic inlays (Cerec 3D) were adhesively inserted. Replicas were taken before and after thermomechanical loading (1.200.000 cycles, 50/5°C, max. load 49 N). Marginal integrity (tooth-composite, composite-inlay) was evaluated with scanning electron microscopy (200×). Percentage of continuous margin (% of total proximal margin length) was compared between groups before and after cycling using ANOVA and Scheffé post-hoc test. RESULTS: After thermomechanical loading, no significant differences were observed between the different groups with respect to the interface composite-inlay and tooth-composite with margins in dentin. The interface tooth-composite in enamel of group EN was significantly better compared to group DE-2In, which was not different to the negative control group DE and DE-1In. CONCLUSION: Margin elevation technique by placement of a composite filling in the proximal box before insertion of a ceramic inlay results in marginal integrities not different from margins of ceramic inlays placed in dentin.

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Short title: Marginal adaptation of ceramic inlays with a proximal margin elevation technique

Key words: Ceramic inlay; subgingival margins; proximal margin elevation technique; marginal adaptation

Declaration of interests:

There are no conflicts of interest.

Abstract

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Methods: Class II MOD-cavities were prepared in 40 human molars and randomly distributed to four groups (n=10). In group EN (positive control) proximal margins were located in enamel, 1 mm above the cementoenamel junction, while 2 mm below in groups DE-1In, DE-2In and DE. The groups DE-1In, DE-2In and DE simulated subgingival location of the cervical margin. In group DE-1In one 3 mm and in group DE-2In two 1.5 mm composite layers (Tetric) were placed for margin elevation of the proximal cavities using Syntac classic as adhesive. The proximal cavities of group DE remained untreated and served as negative control. In all groups, ceramic inlays (Cerec 3D) were adhesively inserted. Replicas were taken before and after thermomechanical loading (1.200.000 cycles, 50/5°C, max. load 49N). Marginal integrity (tooth-composite, composite-inlay) was evaluated with scanning electron microscopy (200x). Percentage of continuous margin (% of total proximal margin length) was compared between groups before and after cycling using ANOVA and Scheffé post-hoc test.

Results: After thermomechanical loading, no significant differences were observed between the different groups with respect to the interface composite-inlay and tooth-composite with margins in dentin. The interface tooth-composite in enamel of group EN was significantly better compared to group DE-2In, which was not different to the negative control group DE and DE-1In.

Conclusion: Margin elevation technique by placement of a composite filling in the proximal box before insertion of a ceramic inlay results in marginal integrities not different from margins of ceramic inlays placed in dentin.

Introduction

Especially in direct class II adhesive restorations, incremental application techniques [1-4], the use of ceramic inserts [5] or the application of a composite base [2,6] have been suggested to counteract the polymerization shrinkage and to reduce stress development within the tooth-restoration system. In situations with extended direct or indirect techniques using e.g. ceramic restorations offer adequate alternatives [7]. However, especially in extended MOD-cavities, which often extend close or below the cementoenamel junction, rubber dam application as well as the adhesive cementation is often difficult to perform. In these situations, a surgical crown lengthening might be useful to allow proper placement of the indirect restoration and to ensure dry conditions during cementation with supragingival margins. Another procedure to relocate cavity margins supragingivally was described by Dietschi et al. [8] by application of a composite base or build-up below indirect restorations. The build-up is covered with an indirect ceramic restoration.

When using the composite filling for relocating the margins to a supragingival level, after insertion of the indirect restoration parts of the composite filling are exposed to the oral environment, which is called “open sandwich technique”. This technique refers to the sandwich technique described for class V composite restorations with glass ionomer as base with the cervical margin of the composite layer located in the glass ionomer cement which is anchored to the cervical dentin. This composite layer fulfils additional requirements like supporting undermined cusps, filling undercuts and providing the necessary geometry for an indirect restoration [9]. These bases and liners may also act as stress absorbers or stress breakers during the insertion and polymerization of subsequent layers or during functional loading. Beside other physical properties, the elastic modulus of the restorative material plays a major role for the stress-absorbing effect [2,6]. In addition to the influence of restorative materials and techniques, different parameters have to be considered to be responsible for the negative impact of polymerization stresses [10], such as configuration factor [11,12], material properties [13], cavity size, presence or absence of enamel at cavity finishing lines and the dentin quality, morphology and location [14,15]. Therefore the indirect restoration technique could help to reduce the polymerization contraction, which relates to the thin layer of resin used for adhesive insertion techniques [16]. Thus, despite the well-behaviour of composite restorations in clinical studies [17], indirect restorations might be indicated in some clinical situations. The idea of the proximal margin elevation technique is to elevate the deep dentinal cervical preparation supragingivally by applying an appropriate increment of composite resin onto the existing margin. This procedure should be performed clinically under rubber dam isolation, following the placement of a matrix. When sufficient rubber dam application is not possible, a potential option to isolate the gingival tissue from the restoration might be seen in the use of a metal matrix adapted with wedges. However placement of an isolating matrix is not possible during indirect restoration cementation. The proximal margin elevation technique by applying a direct composite filling facilitate rubber dam application to ensure a dry working field, which is mandatory for a properly performed adhesive luting procedure [18-20]. Another advantage lies in the simplified approach of optical and conventional impression taking of margins located supragingivally. The use of a proximal margin elevation technique by a composite filling before placement of an indirect restoration has been only described in case reports, as yet [8,21,22]. Thus information about the quality of the proximal margins after functional use is still missing. Therefore, the aim of this in-vitro study was to evaluate the effect of a subgingival proximal margin elevation technique on the marginal adaptation of ceramic inlays after thermomechanical loading and thermocycling.

Accordingly the null hypothesis is that there is no difference in margin quality of ceramic restorations placed in dentin with or without prior proximal margin elevation.

Material and Methods

Specimen preparation

Forty intact, caries-free human molars with completed root formation, which had been stored in 0.1% thymol solution between extraction and use, were selected for this in-vitro test. After cleaning, the molars were randomly assigned to four experimental groups (n = 10). All teeth were prepared for the simulation of pulpal pressure according to a protocol described by Krejci et al. [23]. The roots of the teeth were centrally mounted to roughened specimen carriers (SEM mounts, Baltec AG, Balzers, Liechtenstein) with superglue (Superglue 1733, Renfert, Hilzing, Germany) and embedded in auto-polymerizing resin (Paladur, Heraeus Kulzer, Wehrheim, Germany). The intrapulpal pressure was maintained at 25 mmHg throughout the whole experiment, i.e. during cavity preparation, restoration placement, finishing and thermomechanical loading (TML). Standardized non-bevelled mesial-occlusal-distal (MOD) class II-cavities were prepared under water-cooling using 80 μm diamond burs (Intensiv SA, ISO No. 546524, Grancia, Switzerland). Afterwards, the cavities were finished at a 12x magnification (Stemi 2000, Carl Zeiss, Feldbach, Switzerland) using a 25 μm diamond bur (Intensiv SA, ISO No. 546514). In group EN all cervical margins were located 1 mm above the cementoenamel junction (CEJ), whereas in groups DE-1In, DE-2In and DE all cervical margins were located 2 mm below CEJ. Additional proximal composite layers (Tetric A2, Ivoclar Vivadent, Schaan, Liechtenstein) were applied in group DE-1In with one 3 mm and in group DE-2In with two 1.5 mm thick increments to simulate the proximal margin elevation technique. In group DE the ceramic restoration ended 2 mm below CEJ. Enamel was etched for 30 s and dentin for additionally 15 s with 35% phosphoric acid (Ultraetch, Ultradent, South Jordan, UT, USA), rinsed with water for 40 s and dried with oil-free air. Then, the adhesive system (Syntac Primer, Syntac Adhesive, Heliobond, Ivoclar Vivadent) was applied according to the manufacturer's instructions. The bonding, as well as each increment of the composite were light cured for 40 s (Mode: HIP, 1200 mW/cm^2, Bluephase, Ivoclar Vivadent). After placement of the proximal composite layers, the cervical boxes of the MOD-cavities were located 1 mm above CEJ in group DE-1In and DE-2In and additionally all margins and the composite filling were cleaned using a 25 μm diamond bur. Configuration of cavities and composite increments of experimental groups EN to DE is visualized in figure 1. Each tooth was duplicated with a polyvinylsiloxane (President light body, Coltène, Altstätten, Switzerland) and scan gypsum (CAD/CAM-cast, Dentona, Dortmund, Germany). Optical impressions of these cast were scanned and virtual MOD-inlays were constructed using the Cerec 3D System (Sirona, Bensheim, Germany) with the software version V3.60. Inlays were produced from prefabricated feldspatic ceramic blocs (Vitablocs Mark II, Vita Zahnfabrik, Bad Säckingen, Germany) with a Cerec milling machine (MCXL, Sirona). The fit of the ceramic inlays into the respective cavity was controlled with a low viscosity polyvinylsiloxane (Fit checker, GC, Tokyo, Japan) and stereomicroscope (Stemi 2000, Carl Zeiss) at a 12x magnification. Before cementation the composite fillings in group DE-1In and DE-2In were pre-treated with air abrasion [24] (CoJet, 30 μm, 3M Espe; Seefeld, Germany) for about 5 s followed by extensive cleaning with water spray. Afterwards, all cavities were totally etched (enamel: 30 s; dentin: 15 s) with 35% phosphoric acid (Ultraetch, Ultradent, South Jordan, UT, USA), and subsequently the composite fillings in group DE-1In and DE-2In were silanized (Monobond-S, Ivoclar Vivadent). The silane was applied and left for 1 min before drying without air-blow. Followed by the application of the adhesive system Syntac classic as described above for all groups. The internal surface of the ceramic inlays were first cleaned with alcohol and then etched for 60 s with 5% hydrofluoric acid (Vita Ceramics Etch, Vita Zahnfabrik). After 60 s rinsing and drying, a coupling silane (Monobond-S, Ivoclar Vivadent) was applied and left undisturbed for 60 s followed by air-drying. Afterwards, a thin layer of bonding resin (Heliobond, Ivoclar Viviadent) was applied onto the inner surface of the restoration. The inlays were first manually and then ultrasonically seated with a fine hybrid composite (Tetric A2, Ivoclar Vivadent). With a dental explorer probe, excess material was carefully removed and finally all margins were covered with glycerin gel (Airblock, Dentsply DeTry GmbH, Konstanz, Germany) to avoid oxygen inhibited layer formation. Each side (mesio- and disto-occlusal / -buccal / -lingual) was light-cured for 40 s with a polymerisation light (Mode: HIP, 1200 mW/cm^2, Bluephase, Ivoclar Vivadent) as proposed by Lutz et al. [2]. For controlling the light output of the LED device, a radiometer (Optilux Radiometer, SDS Kerr; Orange, CA, USA) was used to prove that the power was always above 1000 mW/cm^2. All restorations were finished with 15 µm fine diamond burs (Intensiv SA, ISO No. 245504) and polishing discs (Soflex, 3M-ESPE, Rüschlikon, Switzerland) under continuous water cooling and descending roughness. The polishing procedure was observed under a stereomicroscope (Stemi 2000, Carl Zeiss) at 12x magnification.

Thermomechanical loading (TML)

For TML, mesio-palatinal cusps of human maxillary caries-free molars were separated and embedded in Amalgam (Dispersalloy, Dentsply DeTry GmbH) and fixed onto a carrier [25]. These samples were later used as antagonists. The antagonists were stored in water during the whole experiment to avoid desiccation [26]. Then, they were mounted together with the specimens in the sample chambers of the TML machine. The occlusal contacts were marked with articulating paper to ensure that the loading area was in the center of the occlusal inlay surface, not contacting the margins of the preparations. All restored teeth were loaded with repeated thermal and mechanical stresses in a computer-controlled masticator (CoCoM 2, PPK, Zürich, Switzerland) for 1.2 Mio cycles with 49 N at 1.7 Hz [25-27]. Thermal cycling was carried out during the loading cycles by flushing water with temperature changing 6000 times from 5 to 50°C [28].

Quantitative margin analysis

Before (initial) and after (terminal) TML, impressions of the mesial and distal boxes were taken using a polyvinylsiloxane (President light body, Coltène). The impressions were poured out with epoxy resin (Stycast 1266, Emerson & Cuming, Westerlo, Belgium) and luted

(Superglue 1733, Renfert) onto customized specimen holders and sputter-coated with gold (Sputer SCD 030, Balzers Union, Balzers, Liechtenstein). All specimens were examined for a quantitative marginal analysis with a scanning electron microscope (Amray 1810/T, Amray, Bedford, MA, USA) at 10 kV and 200x magnification by one examiner. Two different interfaces were evaluated for marginal integrity. Firstly (tooth-luting composite): the interface between tooth and composite and secondly (luting composite-inlay): the interface between composite and ceramic inlay. All specimens were examined for "continuous" margins (no gap, no interruption of continuity) and imperfect "non-continuous" margins (gap due to adhesive or cohesive failure; restoration or enamel fractures related to restoration margins).

Statistical analysis

Margin quality was measured as a percentage of continuous margins over the total proximal margin length (100% = no discontinuous aspect) at initial and terminal measurement. Statistical analysis was performed with StatView (Version 5.0.1, Abacus Concepts Inc, Piscataway, NJ, USA). Differences among groups were tested using analysis of variance (ANOVA) and Scheffé post-hoc test. The level of significance was set to $p < 0.05$.

Results

Interface: tooth–luting composite with margins in enamel

The percentages of continuous margins are given in Fig. 2.

Initially, for all groups no significant difference in the marginal adaptation was observed ($p = 0.1796$). After TML a significant lower percentage of continuous margins was observed for all groups ($p < 0.0001$, respectively). Also, significant differences between the groups could be recorded at this time point. Thereby, terminal percentage of continuous margin of group EN (90.0 ± 6.4%) was significantly higher compared with that of group DE-2In (83.2 ± 7.1%) ($p = 0.0060$). No significant difference in the terminal percentage of continuous margins was observed when comparing groups DE-2In, DE-1In (85,8 ± 5,3) and DE (87.8 ± 4.3%) ($p = 0.6011$ and $p = 0.7465$, respectively)

Interface: tooth–luting composite with margins in dentin

The percentages of continuous margins are given in Fig. 3.

No statistical significant influence of the different treatment groups on the percentage of continuous margins was observed at initial and terminal evaluation ($p > 0.05$, respectively). When comparing the initial and terminal percentages of continuous margins within the same group, significant lower percentages of continuous margins were observed at the terminal measurement ($p < 0.0001$, respectively) compared to the initial one.

Interface: luting composite–inlay

The percentages of continuous margins are given in Fig. 4.

No statistical significant influence of the different treatment groups on the percentage of continuous margins was observed at initial and terminal evaluation ($p > 0.05$, respectively). When comparing the initial and terminal percentages of continuous margins within the same group, significant lower percentages of continuous margins were observed at the terminal measurement ($p < 0.0001$, respectively) compared to the initial one.

Discussion

The purpose of this study was to determine the influence of a proximal margin elevation technique by application of composite increments in deep cervical MOD-inlay cavities on the marginal adaptation of adhesively luted ceramic inlays. The results support the null hypothesis that no difference was observed in margin quality of ceramic restorations placed in dentin with or without proximal margin elevation. In this in-vitro study, all specimens were subjected to TML. An especially developed loading machine with additional artificial aging through thermocycling was used as well-proven and established approach to simulate the clinical situation [25,29,30]. The benefit of this method is that for all specimens, stress is standardized and reproducible. To mimic clinical conditions, intra pulpal-pressure was kept constantly on a physiological level. However, it must be noticed that TML only offers an approximation of the clinical conditions. The clinical behaviour of a restoration is additionally influenced by a number of factors, such as applied force, force profile, contact time, sliding movement and clearance of worn material. These factors are not controlled in every phase of the simulation applied [31]. Concerning this, the correlation of in-vitro data to the clinical situation is not necessarily straightforward [32].

However, it has frequently been demonstrated that the marginal adaptation of adhesively inserted restorations disintegrates through TML [30,33-35]. Thus TML as applied is an appropriate tool to test resistance of a restoration towards mechanical and thermal impacts. In this in-vitro study a significant reduction of continuous margin appeared in all groups and for both interfaces from the initial (before TML) to the final (after TML) evaluation. Clinically, the presence of discontinuous margins can be associated with marginal discoloration and recurrent caries [36,37].

The SEM-investigation revealed very low proportions of defects at enamel margins, initially as well as after loading. However, a significant reduction of the continuous margin in enamel of the interface tooth–luting composite was observed terminally for group DE-2In compared with group EN, but not when compared with groups DE-1In and DE. An explanation for this finding could be seen in the higher polymerization stress exerted on the adhesive interfaces with a direct filling technique like in the composite box filling groups DE-1In and DE-2In. The defects observed proved to be mainly tooth micro-fractures. This very favourable finding likely reflects the influence of prism orientation in bonding efficiency to acid etched enamel. It is known that a bevelled margin with enamel prisms cut perpendicularly to their long axis is a configuration more favourable than a butt-margin [10,38]. Actually, larger proportions of enamel micro-cracks were observed in in-vitro mechanical loading tests conducted on cavities with a butt margin design similar to the design in the present study [34,39-41]. Also the margins located in dentin showed low percentages of discontinuity. This result emphasizes the adequate adhesion to dentin in all groups. A study by Watanabe et al. (1996) [42] reported differences in dentin morphology and associated variations in bond strength. The density and orientation of tubules or the remaining dentin thickness appear to have impact on marginal gap formation and microleakage due to the biological variability of this tissue [43], thus compromising the integrity and longevity of restorations [44]. Additionally, the presence of shrinkage-induced gaps at the tooth-luting composite interface may lead to post-operative complications, such as restoration fracture, leakage, sensitivity, staining and recurrent caries in vivo [45]. To reduce the polymerization shrinkage in group DE-2In two increments of a fine hybrid composite were applied for placement of the proximal composite filling, but no differences were found compared to group DE-1In with only a single increment. Before inlay insertion the composite fillings were conditioned through airborne-particle abrasion and after etching by application of a silane coupling agent to decontaminate the surface and to achieve higher bond strength between the luting composite and the proximal composite filling as recommended by Özcan et al. [46]. Nevertheless Onisor et al. evaluated the effect of sandblasting in enamel and dentin and found in an in-vitro study no negative influence of 50 µm Al_2O_3 or 27 µm SiOx powder (CoJet) on the marginal quality in enamel. However, in dentin SiOx powder resulted in decreased marginal adaptation after TML. In this study 5 s sandblasting compared to 20 s in the study of Onisor et al. [47] were applied. The prolonged treatment time might negatively influence the dentin and the possible contamination with silica that creates a problem of wetting [48] by preventing the self-etching Syntac primer from penetrating the collagen fibers.

Previous studies have shown that the use of a resin composite as a base under bonded indirect restorations is a promising option [8,40,49]. Other authors have proposed use of a flowable composite for fabrication of a composite build-up [22,50]. A highly filled microhybrid composite as used in the present study may be the best option from different points of view, as compared to flowable composites, which exhibit high contraction stress during polymerization and may not be sufficiently resistant to deformation under load [51]. In addition, flowable composites are difficult to apply precisely, and may leave excess material in the proximal boxes [52]. On the other hand, highly filled microhybrid composites are quite difficult to adapt to cavity walls in a thin layer because of their viscosity. It has to be noted, that only one brand of luting composite was used. Generally, luting composites, even of similar composition, can differ considerably in their chemical and physical characteristics [53,54], and are hence affected in different ways by light polymerization [55]. For this reason, the results of the present study cannot be discriminately applied to other materials. The idea of the proximal margin elevation technique is to elevate the deep dentinal cervical preparation supragingivally by applying an appropriate increment of composite resin onto the existing margin. This procedure should be performed clinically under rubber dam isolation, following the placement of a matrix like mentioned before. Moreover in cases where the application of the composite increments might have led to excess material, this excess material might be easily removed during preparation of the cavity of an indirect restoration. Removal of excess material that might occur during cementation of an in indirect restoration is often difficult to accomplish, especially in deep cavities. The supragingival elevation of subgingival margins through resin composite application facilitates rubber dam application for the cementation of the ceramic inlays, which is mandatory during adhesive procedure and protects the restoration from contamination by saliva, blood, gingiva, crevicular fluid and humidity in the oral cavity. Moreover, the composite protects the hybridized dentin and thus enables safe airborne-particle abrasion of the composite filling. Airborne-particle abrasion of composite is recommended for increasing bond strength of freshly applied composite to already existing composite restorations [56-58]. Thus, this procedure was also chosen in the present study before cementation of the ceramic inlay onto the composite fillings and the creation of perfectly dry conditions for adhesive luting of the ceramic inlay. Another advantage of using a proximal margin elevation technique under indirect ceramic inlays is given by the fact that the composite filling helps to reduce extensive thickness of the inlay. An extensive inlay thickness may impair proper light curing of the resin used for cementation through the ceramic [59,60]. It has been demonstrated that proper light activation is possible through ceramic inlays [61]. In this study a solely light curing composite with the advantage of providing a convenient working time was used. The complete polymerization of luting composite by means of single light activation is dependent on the thickness and opacity of the restorative material [62,63]. Due to this, a powerful light curing system and sufficient irradiation time (40 seconds on each restoration surface) were applied. It might be argued that even slightly subgingival located margins may affect gingival or periodontal health [64] and that therefore subgingival location of margins should be avoided whenever possible. However, Paolantonio et al. [65] found no clinical changes in periodontal tissues adjacent to subgingival resin composite restorations, when filling margins were well contoured and finished and the patient's oral hygiene was excellent. Nevertheless it has to be emphasized that the extent of the biological width between the cervical aspect of the proximal composite box and the alveolar bone should be respected [66].

Conclusion

Under the experimental conditions of this in-vitro study, it can be concluded that the proximal margin elevation composite technique by placement of a composite filling in the proximal box before insertion of a ceramic inlay results in marginal integrities not different from margins of ceramic inlays placed in dentin. Nevertheless, under clinical conditions with margins located at a subgingival level, this technique might be helpful to facilitate insertion of indirect restorations.

References

[1] Bertolotti RL. Posterior composite technique utilizing directed polymerization shrinkage and a novel matrix. Pract Periodontics Aesthet Dent 1991;3:53-58.

[2] Lutz F, Krejci I, Oldenburg TR. Elimination of polymerization stresses at the margins of posterior composite resin restorations: a new restorative technique. Quintessence Int 1986;17:777-84.

[3] Lutz F, Krejci I, Luescher B, Oldenburg TR. Improved proximal margin adaptation of Class II composite resin restorations by use of light-reflecting wedges. Quintessence Int 1986;17:659-64.

[4] Weaver WS, Blank LW, Pelleu GBJ. A visible-light-activated resin cured through tooth structure. Gen Dent 1988;36:236-37.

[5] Donly KJ, Wild TW, Bowen RL, Jensen ME. An in vitro investigation of the effects of glass inserts on the effective composite resin polymerization shrinkage. J Dent Res 1989;68:1234-37.

[6] Friedl KH, Schmalz G, Hiller KA, Mortazavi F. Marginal adaptation of composite restorations versus hybrid ionomer/composite sandwich restorations. Oper Dent 1997;22:21-29.

[7] Dietschi D, Spreafico R. Adhesive metal-free restorations: current concepts for the esthetic treatment of posterior teeth. Quintessence 1997;60-77.

[8] Dietschi D, Spreafico R. Current clinical concepts for adhesive cementation of tooth-colored posterior restorations. Pract Periodontics Aesthet Dent 1998;10:47-54; quiz 56.

[9] Moscovich H, Roeters FJ, Verdonschot N, de Kanter RJ, Creugers NH. Effect of composite basing on the resistance to bulk fracture of industrial porcelain inlays. J Dent 1998;26:183-89.

[10] Carvalho RM, Santiago SL, Fernandes CA, Suh BI, Pashley DH. Effects of prism orientation on tensile strength of enamel. J Adhes Dent 2000;2:251-57.

[11] Feilzer AJ, de Gee AJ, Davidson CL. Setting stresses in composites for two different curing modes. Dent Mater 1993;9:2-5.

[12] Yoshikawa T, Sano H, Burrow MF, Tagami J, Pashley DH. Effects of dentin depth and cavity configuration on bond strength. J Dent Res 1999;78:898-905.

[13] Kemp-Scholte CM, Davidson CL. Marginal integrity related to bond strength and strain capacity of composite resin restorative systems. J Prosthet Dent 1990;64:658-64.

[14] Perdigao J, Swift EJ. Analysis of dental adhesive systems using scanning electron microscopy. Int Dent J 1994;44:349-59.

[15] Shono Y, Ogawa T, Terashita M, Carvalho RM, Pashley EL, Pashley DH. Regional measurement of resin-dentin bonding as an array. J Dent Res 1999;78:699-705.

[16] Wendt SLJ, Leinfelder KF. The clinical evaluation of heat-treated composite resin inlays. J Am Dent Assoc 1990;120:177-81.

[17] Manhart J, Chen H, Hamm G, Hickel R. Buonocore Memorial Lecture. Review of the clinical survival of direct and indirect restorations in posterior teeth of the permanent dentition. Oper Dent 2004;29:481-508.

[18] Kaneshima T, Yatani H, Kasai T, Watanabe EK, Yamashita A. The influence of blood contamination on bond strengths between dentin and an adhesive resin cement. Oper Dent 2000;25:195-201.

[19] Park JW, Lee KC. The influence of salivary contamination on shear bond strength of dentin adhesive systems. Oper Dent 2004;29:437-42.

[20] Tachibana A, Castanho GM, Vieira SN, Matos AB. Influence of Blood Contamination on Bond Strength of a Self-etching Adhesive to Dental Tissues. J Adhes Dent 2010

[21] Spreafico RC, Krejci I, Dietschi D. Clinical performance and marginal adaptation of class II direct and semidirect composite restorations over 3.5 years in vivo. J Dent 2005;33:499-507.

[22] Veneziani M. Adhesive restorations in the posterior area with subgingival cervical margins: new classification and differentiated treatment approach. Eur J Esthet Dent 2010;5:50-76.

[23] Krejci I, Kuster M, Lutz F. Influence of dentinal fluid and stress on marginal adaptation of resin composites. J Dent Res 1993;72:490-94.

[24] Hannig C, Laubach S, Hahn P, Attin T. Shear bond strength of repaired adhesive filling materials using different repair procedures. J Adhes Dent 2006;8:35-40.

[25] Krejci I, Reich T, Lutz F, Albertoni M. [An in vitro test procedure for evaluating dental restoration systems. 1. A computer-controlled mastication simulator]. Schweiz Monatsschr Zahnmed 1990;100:953-60.

[26] Krejci I, Albertoni M, Lutz F. [An in-vitro test procedure for evaluating dental restoration systems. 2. Toothbrush/toothpaste abrasion and chemical degradation]. Schweiz Monatsschr Zahnmed 1990;100:1164-68.

[27] Krejci I, Lutz F. [In-vitro test results of the evaluation of dental restoration systems. Correlation with in-vivo results]. Schweiz Monatsschr Zahnmed 1990;100:1445-49.

[28] Gohring TN, Besek MJ, Schmidlin PR. Attritional wear and abrasive surface alterations of composite resin materials in vitro. J Dent 2002;30:119-27.

[29] Gohring TN, Schonenberger KA, Lutz F. Potential of restorative systems with simplified adhesives: quantitative analysis of wear and marginal adaptation in vitro. Am J Dent 2003;16:275-82.

[30] Manhart J, Schmidt M, Chen HY, Kunzelmann KH, Hickel R. Marginal quality of tooth-colored restorations in class II cavities after artificial aging. Oper Dent 2001;26:357-66.

[31] Heintze SD. How to qualify and validate wear simulation devices and methods. Dent Mater 2006;22:712-34.

[32] Lambrechts P, Debels E, Van Landuyt K, Peumans M, Van Meerbeek B. How to simulate wear? Overview of existing methods. Dent Mater 2006;22:693-701.

[33] Bortolotto T, Onisor I, Krejci I. Proximal direct composite restorations and chairside CAD/CAM inlays: marginal adaptation of a two-step self-etch adhesive with and without selective enamel conditioning. Clin Oral Investig 2007;11:35-43.

[34] Dietschi D, Moor L. Evaluation of the marginal and internal adaptation of different ceramic and composite inlay systems after an in vitro fatigue test. J Adhes Dent 1999;1:41-56.

[35] Frankenberger R, Lohbauer U, Schaible RB, Nikolaenko SA, Naumann M. Luting of ceramic inlays in vitro: marginal quality of self-etch and etch-and-rinse adhesives versus self-etch cements. Dent Mater 2008;24:185-91.

[36] Fasbinder DJ. Clinical performance of chairside CAD/CAM restorations. J Am Dent Assoc 2006;137 Suppl:22S-31S.

[37] Opdam NJ, Bronkhorst EM, Roeters JM, Loomans BA. Longevity and reasons for failure of sandwich and total-etch posterior composite resin restorations. J Adhes Dent 2007;9:469-75.

[38] Munechika T, Suzuki K, Nishiyama M, Ohashi M, Horie K. A comparison of the tensile bond strengths of composite resins to longitudinal and transverse sections of enamel prisms in human teeth. J Dent Res 1984;63:1079-82.

[39] Dietschi D, Herzfeld D. In vitro evaluation of marginal and internal adaptation of class II resin composite restorations after thermal and occlusal stressing. Eur J Oral Sci 1998;106:1033-42.

[40] Dietschi D, Olsburgh S, Krejci I, Davidson C. In vitro evaluation of marginal and internal adaptation after occlusal stressing of indirect class II composite restorations with different resinous bases. Eur J Oral Sci 2003;111:73-80.

[41] Krejci I, Lutz F, Reimer M. Marginal adaptation and fit of adhesive ceramic inlays. J Dent 1993;21:39-46.

[42] Watanabe LG, Marshall GWJ, Marshall SJ. Dentin shear strength: effects of tubule orientation and intratooth location. Dent Mater 1996;12:109-15.

[43] Pashley DH. Dentin: a dynamic substrate--a review. Scanning Microsc 1989;3:161-74; discussion 174-6.

[44] Santini A, Milia E. Microleakage around a low-shrinkage composite cured with a high-performance light. Am J Dent 2004;17:118-22.

[45] Hickel R, Manhart J. Longevity of restorations in posterior teeth and reasons for failure. J Adhes Dent 2001;3:45-64.

[46] Ozcan M, Alander P, Vallittu PK, Huysmans MC, Kalk W. Effect of three surface conditioning methods to improve bond strength of particulate filler resin composites. J Mater Sci Mater Med 2005;16:21-27.

[47] Onisor I, Bouillaguet S, Krejci I. Influence of different surface treatments on marginal adaptation in enamel and dentin. J Adhes Dent 2007;9:297-303.

[48] BUONOCORE MG. PRINCIPLES OF ADHESIVE RETENTION AND ADHESIVE RESTORATIVE MATERIALS. J Am Dent Assoc 1963;67:382-91.

[49] Hofmann N, Just N, Haller B, Hugo B, Klaiber B. The effect of glass ionomer cement or composite resin bases on restoration of cuspal stiffness of endodontically treated premolars in vitro. Clin Oral Investig 1998;2:77-83.

[50] Olsburgh S. Graduation thesis. Geneva: Geneva University 2000

[51] De Munck J, Van Landuyt KL, Coutinho E, Poitevin A, Peumans M, Lambrechts P et al. Fatigue resistance of dentin/composite interfaces with an additional intermediate elastic layer. Eur J Oral Sci 2005;113:77-82.

[52] Frankenberger R, Kramer N, Pelka M, Petschelt A. Internal adaptation and overhang formation of direct Class II resin composite restorations. Clin Oral Investig 1999;3:208-15.

[53] Caughman WF, Chan DC, Rueggeberg FA. Curing potential of dual-polymerizable resin cements in simulated clinical situations. J Prosthet Dent 2001;86:101-06.

[54] Kumbuloglu O, Lassila LV, User A, Vallittu PK. A study of the physical and chemical properties of four resin composite luting cements. Int J Prosthodont 2004;17:357-63.

[55] Braga RR, Cesar PF, Gonzaga CC. Mechanical properties of resin cements with different activation modes. J Oral Rehabil 2002;29:257-62.

[56] Ozcan M, Cura C, Brendeke J. Effect of aging conditions on the repair bond strength of a microhybrid and a nanohybrid resin composite. J Adhes Dent 2010;12:451-59.

[57] Rinastiti M, Ozcan M, Siswomihardjo W, Busscher HJ. Immediate repair bond strengths of microhybrid, nanohybrid and nanofilled composites after different surface treatments. J Dent 2010;38:29-38.

[58] Rinastiti M, Ozcan M, Siswomihardjo W, Busscher HJ. Effects of surface conditioning on repair bond strengths of non-aged and aged microhybrid, nanohybrid, and nanofilled composite resins. Clin Oral Investig 2010

[59] Schulte AG, Vockler A, Reinhardt R. Longevity of ceramic inlays and onlays luted with a solely light-curing composite resin. J Dent 2005;33:433-42.

[60] Soh MS, Yap AU, Siow KS. The effectiveness of cure of LED and halogen curing lights at varying cavity depths. Oper Dent 2003;28:707-15.

[61] Besek M, Mormann WH, Persi C, Lutz F. [The curing of composites under Cerec inlays]. Schweiz Monatsschr Zahnmed 1995;105:1123-28.

[62] Blackman R, Barghi N, Duke E. Influence of ceramic thickness on the polymerization of light-cured resin cement. J Prosthet Dent 1990;63:295-300.

[63] Cardash HS, Baharav H, Pilo R, Ben-Amar A. The effect of porcelain color on the hardness of luting composite resin cement. J Prosthet Dent 1993;69:620-23.

[64] Broadbent JM, Williams KB, Thomson WM, Williams SM. Dental restorations: a risk factor for periodontal attachment loss? J Clin Periodontol 2006;33:803-10.

[65] Paolantonio M, D'ercole S, Perinetti G, Tripodi D, Catamo G, Serra E et al. Clinical and microbiological effects of different restorative materials on the periodontal tissues adjacent to subgingival class V restorations. J Clin Periodontol 2004;31:200-07.

[66] Kamin S. The biologic width--periodontal-restorative relationship. Singapore Dent J 1989;14:13-15.

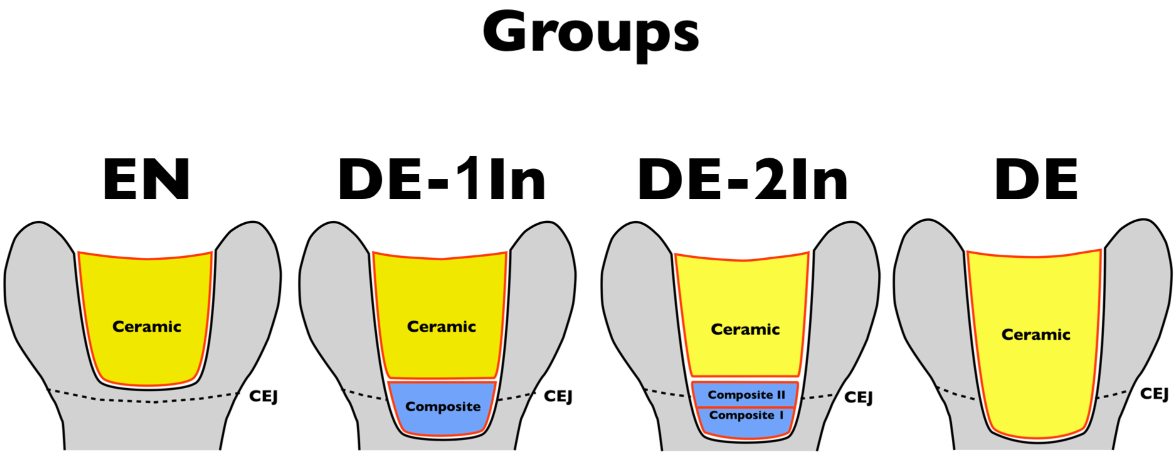
Groups
EN
DE-1In
DE-2In
DE
Ceramic
Composite
Composite II
Composite I
CEJ

Fig. 1

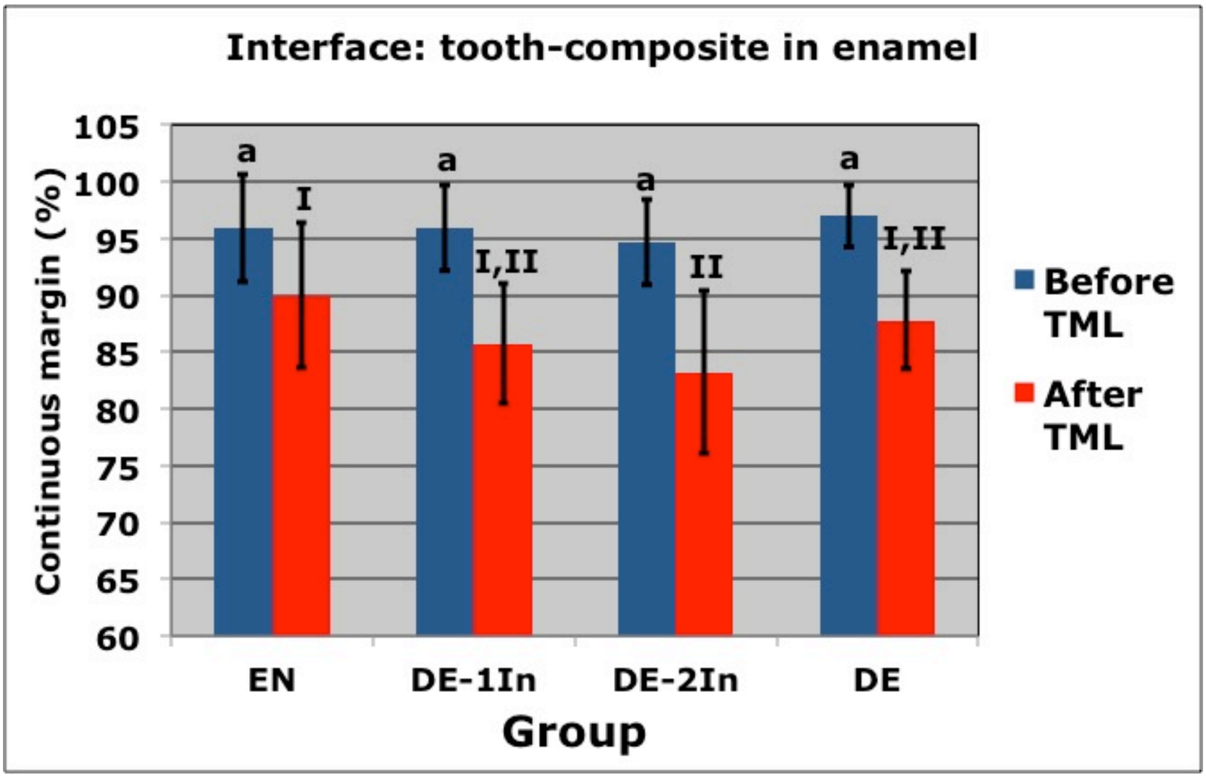
Interface: tooth-composite in enamel
Continuous margin (%)
105
100
95
90
85
80
75
70
65
60
a
I
I,II
II
EN
DE-1In
DE-2In
DE
Group
Before TML
After TML

Fig. 2

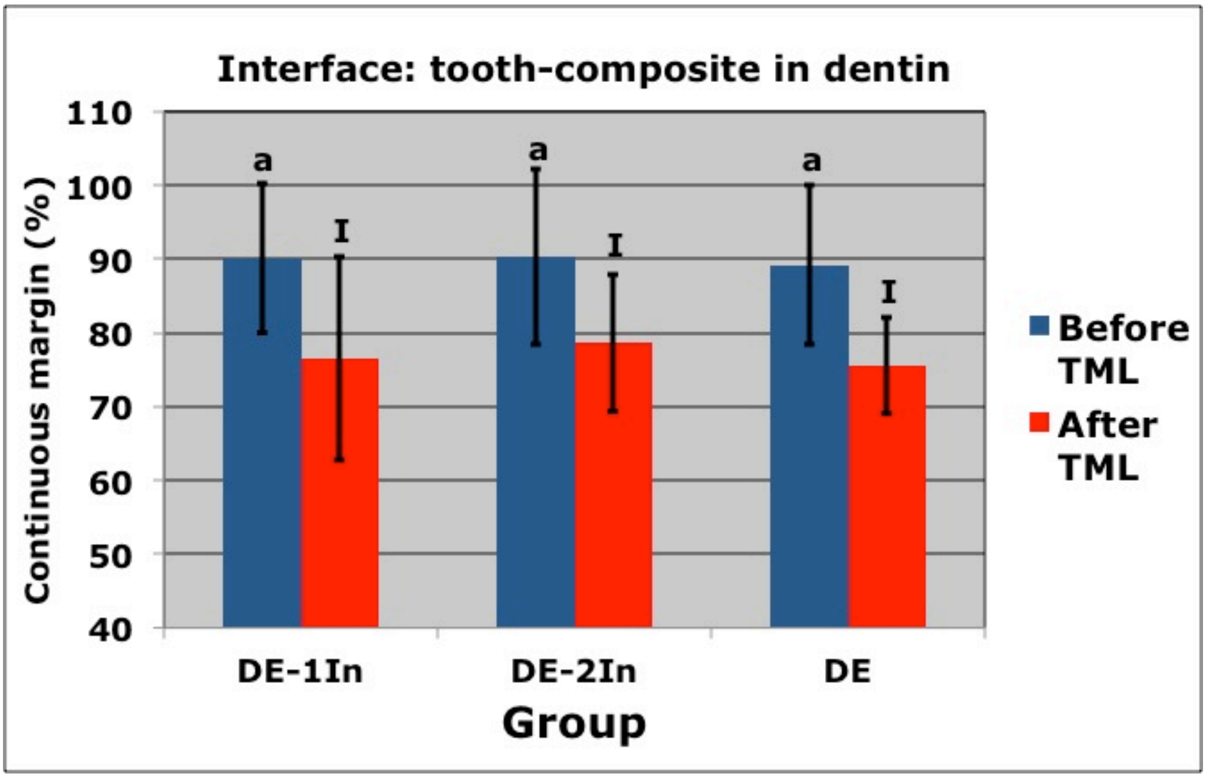
Interface: tooth-composite in dentin
Continuous margin (%)
110
100
90
80
70
60
50
40
a
I
DE-1In
DE-2In
DE
Group
Before TML
After TML

Fig. 3

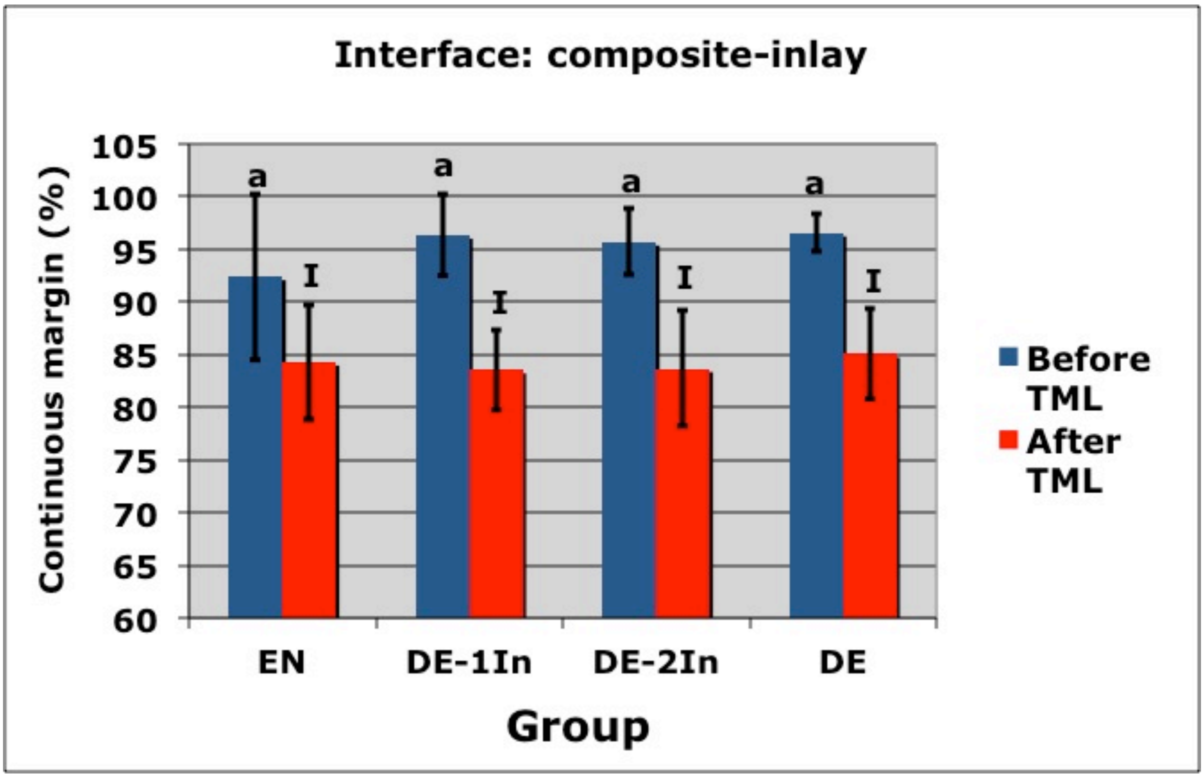
Interface: composite-inlay
Continuous margin (%)
105
100
95
90
85
80
75
70
65
60
a
I
EN
DE-1In
DE-2In
DE
Group
Before TML
After TML

Fig. 4

Tab. 3: Interface: luting composite–inlay

Percentages (mean ± SD) of continuous margins in the experimental groups EN, DE-1In, DE-2In and DE as determined before and after TML. Groups indicated with the same superscript letter were not statistically significantly different.

Fig. 1: Description of experimental groups EN, DE-1In, DE-2In and DE

Fig. 2: Continuous margins in enamel of the interface: tooth–luting composite

Percentages (mean ± SD) of continuous margins in the experimental groups EN, DE-1In, DE-2In and DE as determined before and after TML. Groups indicated with the same superscript letter were not statistically significantly different.

Fig. 3: Continuous margins in dentin of the interface: tooth–luting composite

Percentages (mean ± SD) of continuous margins in the experimental groups DE-1In, DE-2In and DE as determined before and after TML. Groups indicated with the same superscript letter were not statistically significantly different.

Fig. 4: Continuous margins of the interface: luting composite-inlay

Table 1. Interface: tooth-luting composite in enamel

Percentages (mean ± SD) of continuous margins in the experimental groups EN, DE-1In, DE-2In and DE as determined before and after TML. Additionally, the results of the statistical analysis are given. Groups indicated with the same superscript letter were not statistically significantly different.

Group	Description	Initially	Terminally
EN	no margin elevation (enamel)	95.9 ± 4.7 ^{a}	90.0 ± 6.4 ^{I}
DE-1In	margin elevation (1 increment)	95.9 ± 3.7 ^{a}	85.8 ± 5.3 $^{I, II}$
DE-2In	margin elevation (2 increments)	94.7 ± 3.7 ^{a}	83.2 ± 7.1 ^{II}
DE	no margin elevation (dentin)	97.0 ± 2.7 ^{a}	87.8 ± 4.3 $^{I, II}$

Table 2. Interface: tooth-luting composite in dentin

Percentages (mean ± SD) of continuous margins in the experimental groups DE-1In, DE-2In and DE as determined before and after TML. Additionally, the results of the statistical analysis are given. Groups indicated with the same superscript letter were not statistically significantly different.

Group	Description	Initially	Terminally
DE-1In	margin elevation (1 increment)	90.1 ± 10.1 ^{a}	76.5 ± 13.7 ^{I}
DE-2In	margin elevation (2 increments)	90.3 ± 12.0 ^{a}	78.6 ± 9.3 ^{I}
DE	no margin elevation (dentin)	89.2 ± 10.8 ^{a}	75.6 ± 6.6 ^{I}

Table 3. Interface: luting composite-inlay

Percentages (mean ± SD) of continuous margins in the experimental groups EN, DE-1In, DE-2In and DE as determined before and after TML. Additionally, the results of the statistical analysis are given. Groups indicated with the same superscript letter were not statistically significantly different.

Group	Description	Initially	Terminally
EN	no margin elevation (enamel)	92.4 ± 7.9^{a}	84.3 ± 5.5^{I}
DE-1In	margin elevation (1 increment)	96.4 ± 3.8^{a}	83.6 ± 3.8^{I}
DE-2In	margin elevation (2 increments)	95.7 ± 3.1^{a}	83.7 ± 5.5^{I}
DE	no margin elevation (dentin)	96.6 ± 1.8^{a}	85.1 ± 4.3^{I}